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Outbreaks associated with recreational water in the United States

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Abstract
In this article, we review the causes of outbreaks associated with recreational water during 1971 – 2000. A bacterial or protozoan etiology was identified in three-quarters of the outbreaks; 23% of the outbreaks were of undetermined etiology. The most frequently identified agents were *Cryptosporidium* (15%), *Pseudomonas* (14%), *Shigella* (13%), *Naegleria* (11%), *Giardia* (6%), and toxigenic *E. coli* (6%). Outbreaks attributed to *Shigella*, *E. coli* O157:H7, and *Naegleria* were primarily associated with swimming in fresh waters such as lakes, ponds, and rivers. In contrast, outbreaks caused by *Cryptosporidium* and *Giardia* were primarily associated with treated water in swimming and wading pools. Important sources of contamination for both treated and untreated recreational waters were the bathers themselves. Contamination from sewage discharges and wild or domestic animals were also important sources for untreated waters. Contributing factors in swimming-pool outbreaks were inadequate attention to maintenance, operation, disinfection, and filtration. Although not all waterborne outbreaks are recognized nor reported, the national surveillance of these outbreaks has helped identify important sources of contamination of recreational waters and the etiologic agents. This information can affect prevention recommendations and research priorities that may lead to improved water quality guidelines.

Keywords: *Waterborne disease, waterborne pathogens, swimming and bathing, water quality*

Introduction

In 1971, the U.S. Environmental Protection Agency (EPA), the Centers for Disease Control and Prevention (CDC), and the Council of State and Territorial Epidemiologists initiated a surveillance system for reporting the occurrence and causes of waterborne outbreaks in the United States (Craun et al. 1990). State and local health agencies have primary responsibility for detecting and investigating waterborne outbreaks which are then voluntarily reported to the CDC and EPA. The surveillance system provides information about outbreaks associated with drinking water systems and other types of water. Recently, national statistics were reported for outbreaks associated with recreational water during 2001 – 2002 (Yoder et al.

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2004). To supplement these recent statistics, we reviewed the historical information for waterborne outbreaks reported during 1971 – 2000. Recreational waters encompass swimming and wading pools, thermal and other natural springs, fresh and marine waters, water parks, interactive fountains, and other venues where water contact may take place. Fresh and marine waters are classified as untreated water; treated waters refer to the remaining recreational venues. Occasionally, an outbreak may be reported in a private swimming or wading pool that is a drain and fill type with no additional disinfection or filtration.

Yoder et al. (2004) included statistics for outbreaks associated with the use of whirlpools or hot tubs. In our review, we include these outbreaks only when persons also had a swimming pool exposure that was associated with illness. Also not included in this review are outbreaks on cruise ships operating from U.S. ports and wound infections associated with water recreation.

Methods

Information about the outbreaks reviewed here were obtained from the CDC-EPA database and surveillance summaries that have been published biennially or annually since 1973 (CDC 1973, 1974, 1976a, 1976b, 1977, 1979, 1980, 1981, 1982a, 1982b, 1983, 1984, 1985, St. Louis 1988; Levine and Craun 1990; Herwaldt et al. 1991; Moore et al. 1993; Kramer et al. 1996; Levy et al. 1998; Barwick et al. 2000; Lee et al. 2002). In 1978, the CDC began to specifically request information about recreational water outbreaks from state health agencies. Before then, recreational water outbreaks were sporadically reported, and in the early years, the database included several outbreaks reported in the literature.

Waterborne outbreak surveillance

Information available from the surveillance system pertains to outbreaks voluntarily reported. The outbreaks are classified according to the strength of the epidemiologic evidence implicating water as the vehicle of transmission. At least two persons must experience a similar illness after the ingestion of or contact with water, and epidemiologic evidence must implicate water as the probable source of the illness. Exceptions are single cases of laboratory-confirmed, primary amebic meningoencephalitis (PAM) and chemical poisoning if water-quality data indicate contamination by the chemical.

Since resources available for outbreak investigations differ from locality to locality and not all outbreaks are rigorously investigated (Craun et al. 2001; Yoder et al. 2004), the reported outbreaks do not always contain complete information about the number of ill or exposed persons, duration of illness, etiologic agent, or suspected sources of contamination. Outbreaks without water quality data or with incomplete information about sources of contamination are included in the surveillance data if the epidemiologic evidence implicates water (Lee et al. 2002; Yoder et al. 2004).

The surveillance system does not include endemic illnesses that may be associated with recreational water. In addition, not all outbreaks are recognized, investigated, or reported, and not all outbreaks are sufficiently investigated to estimate the total number of persons who may have been affected. The likelihood that individual cases of illness will be detected and investigated is dependent on many factors including: (a) public awareness of waterborne illnesses, (b) local requirements for reporting cases of particular diseases, (c) the surveillance and investigative activities of state and local public health and environmental agencies, and (d) availability of and extent of laboratory facilities. Outbreaks associated with recreational water are difficult to recognize and investigate because they usually result from persons who congregate in one venue and then disperse among the community or to other localities. Ill persons may consult different health-care providers, and different health districts may have jurisdiction for surveillance and investigation. Reliable estimates of the number of unrecognized and unreported waterborne outbreaks or illnesses are not available (Yoder et al. 2004).

Results

Outbreak statistics

During 1971 – 2000, the surveillance system contained information about 259 outbreaks and an estimated 21,740 cases of illness, 36 emergency room visits, 206 hospitalizations, and 28 deaths (Table I). Most (58%) illnesses were associated with protozoan outbreaks, and most (67%) hospitalizations and emergency room visits were associated with bacterial outbreaks. Most frequently, exposure to contaminated recreational waters resulted in acute gastroenteritis and dermatitis (Table II). Gastroenteritis was reported in 61% of the outbreaks and 85% of the illnesses. Dermatitis was reported in 20% of the outbreaks and 8% of the illnesses. PAM was reported in 28 single-case outbreaks. Occasionally, outbreaks of typhoid fever, infectious hepatitis, leptospirosis, and other illnesses were reported.

Outbreaks were primarily associated with recreational activities in lakes or ponds and swim pools (Table III). Other venues included wading pools, water slides, wave pools, interactive water fountains, rivers, canals, springs, and creeks. In one outbreak, 61 persons who volunteered for a dunking booth at a local fair became ill after accidentally swallowing water (Moore et al. 1993).

Reporting trends. Almost two-thirds of the outbreaks were reported during 1991 – 2000 (Figure 1). The recent increase in the number of outbreaks may be due, in part, to increased recreational activities and increased exposure to contaminated water; however, improved surveillance and outbreak detection, investigation, and reporting by public health agencies are also important. There has been a greater public awareness of waterborne pathogens such as *Giardia, Cryptosporidium*, and *E. coli* O157:H7 and more prompt reporting of these illnesses to health agencies in recent years. Reporting was inconsistent during the first half of the 30-year surveillance period when fewer than five outbreaks were reported in each of 11 years. In three of these years, no outbreaks were reported. The increase in the number of outbreaks was primarily due to outbreaks associated with gastroenteritis symptoms (Figure 2). An increased

Table I. Etiology, recreational water outbreaks, USA, 1971—2000.

	Outbreaks		Cases of Illness	
Etiology	(*n*)	%	(*n*)	%
Protozoa	97	37.5	12 701	58.4
Bacteria	97	37.5	4 548	20.9
Unidentified agents	40	15.4	2 966	13.6
Viruses	18	6.9	1 433	6.6
Chemicals	5	1.9	40	0.2
Bacteria and protozoa	1	0.4	38	0.2
Algae	1	0.4	14	0.1
Totals	259	100.0	21 740	100.0

Table II. Disease or Symptoms, Recreational Water Outbreaks, USA, 1971—2000.

	Outbreaks		Cases of illness	
Disease or symptoms	(*n*)	%	(*n*)	%
Gastroenteritis	157	60.6	18 584	85.5
Non-chemical dermatitis[a]	49	18.9	1 761	8.1
Primary amebic meningoencephalitis	28	10.8	28	0.1
Leptospirosis	7	2.7	426	2.0
Conjunctivitis[b], pharyngitis, or aseptic meningitis (adenovirus or enterovirus)	6	2.3	746	3.4
Otitis externa	3	1.2	118	0.5
Chemical dermatitis	3	1.2	34	0.1
Hepatitis	2	0.8	26	0.1
Typhoid fever	2	0.8	11	0.1
Chemical bronchial irritation	1	0.4	3	< 0.1
Chemical keratitis	1	0.4	3	< 0.1

[a] includes one outbreak (35 cases) of dermatitis with otitis externa. [b] includes one outbreak (5 cases) of dermatitis with conjunctival irritation.

Table III. Water source, recreational water outbreaks, USA, 1971—2000.

	Outbreaks		Cases of illness	
Recreational water	(*n*)	%	(*n*)	%
Lake or pond	116	44.8	7 559	34.8
Swimming pool only	72	27.8	11 692	53.8
Swimming pool and other waters[a]	17	6.6	431	2.0
River, stream, creek, or canal	12	4.6	80	0.4
Wading pool	10	3.9	195	0.9
Water slide, wave pool, or interactive water fountain	7	2.7	1 247	5.7
Spring	7	2.7	137	0.6
Ditch or puddle	6	2.3	22	0.1
Swimming pool and wading pool	5	1.9	268	1.2
Lake, pond, or river and other waters[b]	3	1.2	3	< 0.1
Ocean	2	0.8	44	0.2
Dunking booth	1	0.4	61	0.3
Unknown	1	0.4	1	< 0.1
Totals	259	100.0	21 740	100.0

[a] Swimming pool and whirlpool (7 outbreaks), swimming pool and hot tub (9 outbreaks), and swimming pool and sauna (1 outbreak). [b] Pond and swimming pool (1 outbreak), lake and swimming pool (1 outbreak), and river and wastewater holding pond (1 outbreak).

number of outbreaks were reported for both treated and untreated recreational water (Figure 3). In 2000, 20 outbreaks were associated with swimming, wading, and wave pools, water slides, and interactive fountains, whereas only eight and nine outbreaks were associated with

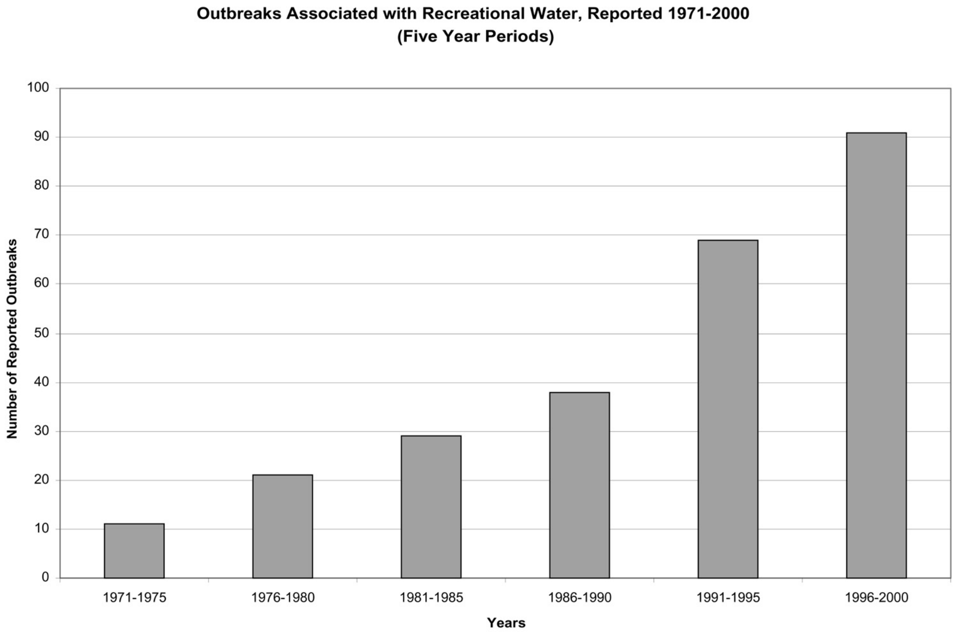


Figure 1.

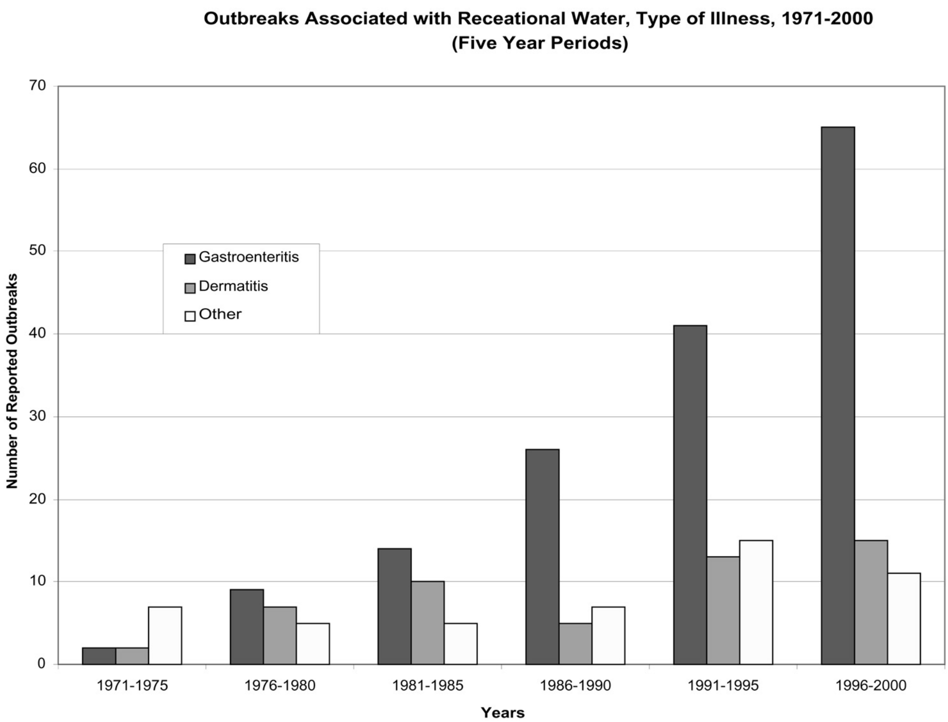


Figure 2.

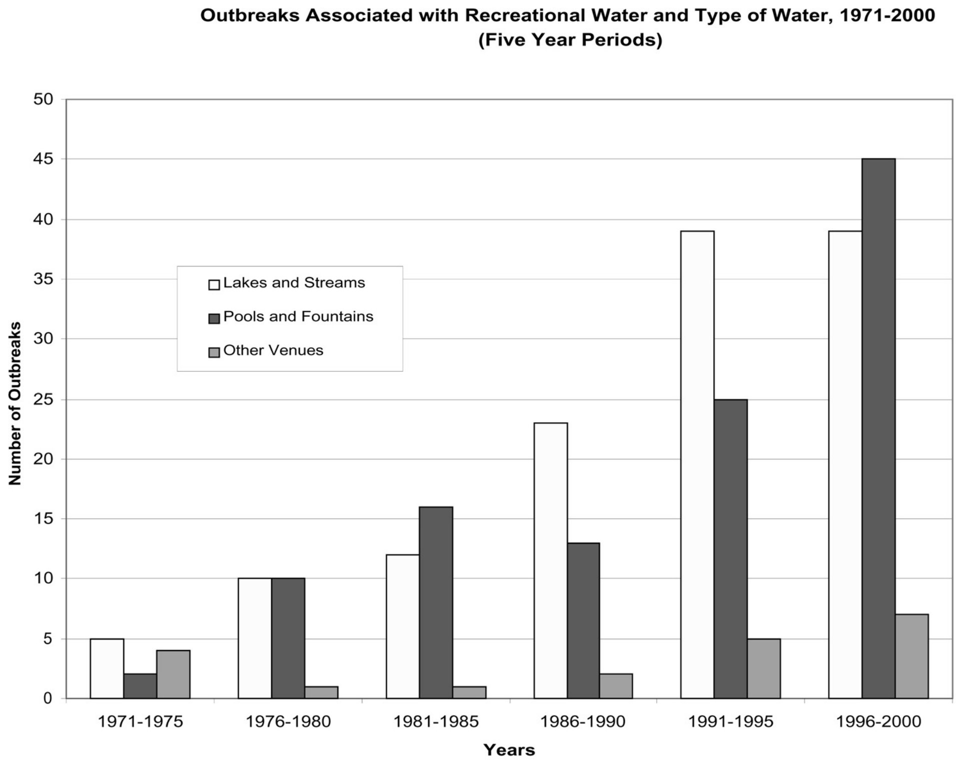


Figure 3.

these venues in 1999 and 1998, respectively. Before 1998, there were only two years when more than five outbreaks were reported in treated recreation water. The number of outbreaks reported during 1991 – 2000 in untreated water venues was significantly greater than the number reported during the previous ten-year period; however, the annual number varied greatly from as few as two outbreaks in 1997 to as many as thirteen in 1995.

Outbreak etiologies. A bacterial or protozoan etiology was identified in most outbreaks (75%) and cases of illness (79%) during 1971 – 2000 (Table I). A viral etiology was identified in only 7% of both outbreaks and illnesses. Exposures to high levels of pool chemicals (chlorine, bromine, sodium hydroxide) caused 2% of the outbreaks and less than 1% of the illnesses. An infectious etiologic agent was suspected but not identified in the remaining outbreaks and illnesses. All but two outbreaks of undetermined etiology resulted in acute gastroenteritis; in these two outbreaks, investigators suspected *Pseudomonas aeruginosa* as the cause of otitis externa and folliculitis.

Almost half (47%) of the protozoan outbreaks were associated with swimming or wading pools and water fountains; 35% of the outbreaks were associated with lakes or ponds. Outbreaks of bacterial etiology were also associated with swimming or wading pools and fountains (45%) and lakes and ponds (46%). In an outbreak that occurred at an interactive water fountain, both a bacterial and protozoan etiology (*Shigella* and *Cryptosporidium*) was identified. Of the 18 reported viral outbreaks, 56% were associated with lakes or ponds.

Two dermatitis outbreaks were associated with marine water. One outbreak was attributed to *Microcoleus lyngbyaceus* algae at an ocean beach in Hawaii (Moore et al. 1993). The second outbreak occurred at an ocean beach in Delaware where local snails were found to contain cercariae of *Austrobilharzia variglandis*, an avian schistosome that can cause cercarial dermatitis (CDC 1982).

In recent years, reports of outbreaks of undetermined etiology have decreased, and outbreaks of protozoan etiologies have increased. Only 11% of the outbreaks reported during 1991–2000 were of undetermined etiology; during 1986–90, 34% of the reported outbreaks were of unknown etiology. During 1991–2000, 50% of the reported outbreaks were caused by protozoa, but only 16% of the outbreaks reported during 1986–90 were caused by protozoa.

Seasonal distribution. The date of occurrence was available for 252 (97%) outbreaks reported during 1971–2000. More than 70% of the outbreaks occurred during June, July, and August when increased numbers of persons participate in water recreation. Persons have access to indoor pools, especially at resorts and motels during cold weather months, and some areas of the United States are warm enough for year-round water recreation. Some 17% of outbreaks occurred during the months of September through February. Almost all (90%) of the outbreaks of gastroenteritis occurred during the summer months. However, almost all (92%) of the outbreaks of dermatitis occurred during the months of September through February.

Severity of illness. The number of illnesses associated with outbreaks varied during the 30-year period. In 1981 only 14 illnesses were reported; 5,623 illnesses were reported in 1995. The largest outbreaks occurred most recently when an average of 137 and 83 illnesses per outbreak were reported during 1991–95 and 1996–2000, respectively (Figure 4).

Although information was not always reported about the severity of illness, at least 75 outbreaks (29%) resulted in one or more hospital admissions. Hospitalizations were caused by various etiologic agents. The most frequent admissions were for persons diagnosed with shigellosis (32%), cryptosporidiosis (24%), *E. coli* O157:H7 gastroenteritis (18%), and

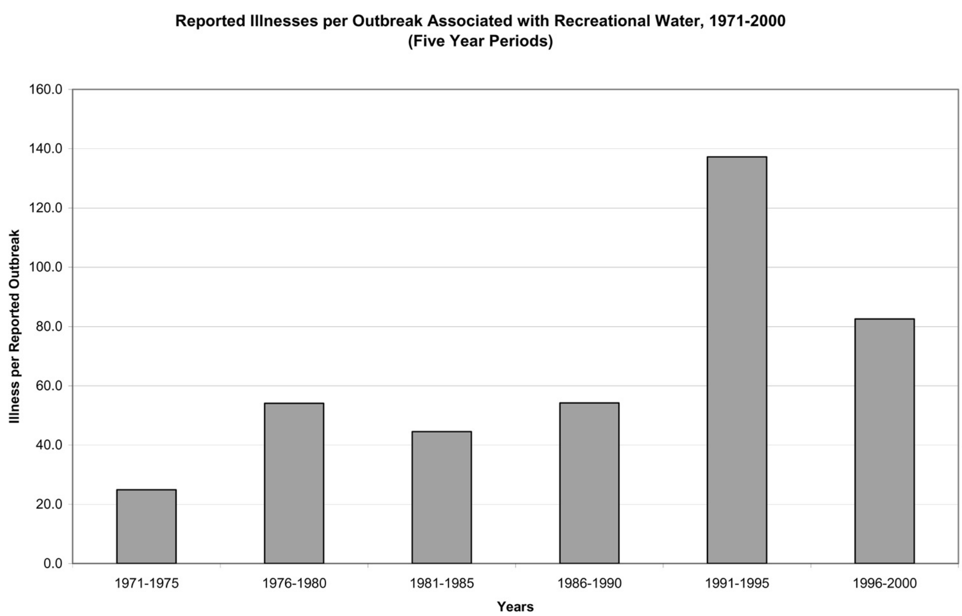


Figure 4.

leptospirosis (14%). In an additional four outbreaks, persons visited a hospital emergency room, primarily for medical treatment of shigellosis. Shigellosis is characterized by diarrhea accompanied by fever, nausea and sometimes vomiting, cramps, and tenesmus. In typical cases, the stools contain blood and mucus.

PAM, an infection of the central nervous system caused by free-living ameba *Naegleria fowleri*, usually occurs within 5–8 days after swimming and diving in warm fresh or brackish water. The majority of cases have been reported from states with more temperate climates like Florida and Texas, but cases have also been associated with lakes and ponds in Arkansas, North Carolina, New York, and Oklahoma and a thermal spring in California. The portal of entry is probably the nasal mucosa overlying the cribriform plate during underwater swimming and diving (Visvesvara and Stehr-Green 1990; CDC 1991). Infection is almost always fatal. Twenty-seven persons, mostly children and young adults 3–19 years old, died after becoming infected during the 30-year surveillance period. A single non-fatal case was reported; a nine-year-old child survived after being infected while bathing in a thermal spring.

A single death was associated with *E. coli* O157:H7, a pathogen that can elaborate potent cytotoxins and cause hemolytic-uremic syndrome. Diarrhea can be mild or very severe with stools that are virtually all blood.

Sources of contamination and deficiencies. In about half of the outbreaks reported during 1971–2000, information was available about sources of contamination and contributing factors such as a high density of bathers. Multiple sources of contamination and deficiencies including inadequate disinfection were reported in several outbreaks.

Inadequate attention to maintenance, operation, or treatment (e.g., disinfection or filtration) was frequently reported in treated-water outbreaks. Important sources of contamination for both treated and untreated waters included fecal accidents, ill bathers, and diaper-age children (Table IV). In several outbreaks, adults were reported rinsing diapers in the water. High bather density, heavy bather use, and bather crowding were often cited as the possible source of contamination or as a contributing factor. Overcrowding was a subjective conclusion based on investigators' comments. For example, investigators may have noted that the outbreak occurred during a time when the facility had a very large number of bathers due to a holiday, special event, or high temperatures

Table IV. Source of contamination and deficiencies, recreational water outbreaks, USA, 1971–2000.

	Percentage of outbreaks with listed contamination or deficiency [a]	
Source of contamination or deficiency	Treated water (%)	Untreated water (%)
Feces in water or ill bathers	36	31
Poor maintenance or operation; inadequate or malfunctioning filter or disinfection	52	–
Bather overloading or crowding	13	34
Diaper aged children	18	25
Seepage or overflow of sewage	2	21
Animals	2	18
Flooding, heavy rainfall	–	3

[a] Some outbreaks have multiple deficiencies; thus, totals are > 100%. One swimming pool outbreak is included where no treatment was provided.

(e.g., the hottest day of the season). Overcrowding was also noted without additional comments. Sources of contamination for untreated waters included sewage discharges, wildlife, and domestic animals.

Fecal accidents were identified or suspected in 39 outbreaks. In 15 (38%) of these outbreaks, *Cryptosporidium* was the etiologic agent. *E. coli* O15:H7 and *Shigella* each caused seven (18%) outbreaks where fecal accidents were reported. Norovirus and *Giardia* each caused three (8%) and two (5%) outbreaks, respectively. The remaining outbreaks (13%) were of undetermined etiology.

Cryptosporidium or *Shigella* caused most of the 25 outbreaks where diaper-age children were suspected sources of contamination. *Shigella* was identified as the etiologic agent in seven (28%) of these outbreaks, *Cryptosporidium* was identified in 6 (24%), and both agents were identified in one (4%) outbreak.

In the 28 outbreaks where large numbers of bathers were reported or overcrowding was noted, *Shigella* was the most frequently (32%) identified agent; no agent was identified in eleven (39%) outbreaks.

Water quality. Water samples collected during the investigation were found to be coliform-positive in 40 (85%) outbreaks where fecal accidents, diapered children, ill bathers, or bather crowding was reported and in 8 (73%) outbreaks where a sewage discharge was identified. Quantitative information about bacterial water quality was available for relatively few (38) outbreaks (Table V). Less than 500 organisms per 100 ml were detected in 59% of those outbreaks where water samples were analyzed for fecal coliforms, *E. coli*, or fecal streptococcus.

In 1986, EPA recommended microbiological water quality guidelines for fresh and marine recreational waters (EPA 1986; Dufour et al. 1984; Cabelli et al. 1983). The guideline for fresh waters is a monthly geometric mean (based on five equally spaced samples) of $\leqslant$ 33/100 ml for enterococci or $\leqslant$ 126/100 ml for *Escherichia coli*. For marine waters, the monthly geometric mean water quality indicator concentration should be $\leqslant$ 35/100 ml enterococci. State and local governments establish and enforce regulations for recreational water and may use different guidelines, including a single sample maximum value, to determine when to close beaches or post warning signs to alert potential bathers of poor water quality. The water quality of a recreational lake or pond was reported as meeting local bathing water quality standards in 12 (93%) of 13 outbreaks where this information was provided. In these 13 outbreaks, investigation reports provided no information about the limits that were applied. If

Table V. Number of outbreaks with water quality data obtained during outbreak investigations, 1971—2000.

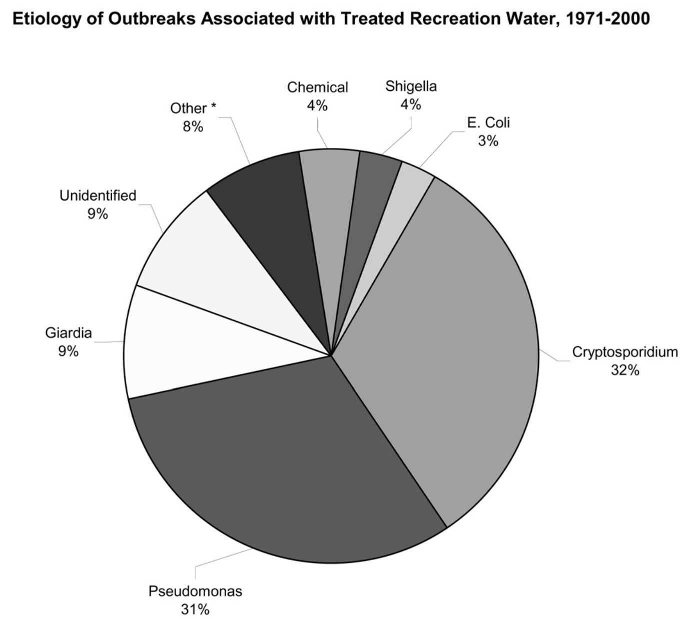
	Number of outbreaks and average number of coliforms/100 ml:		
Recreational water	$\leqslant$ 126/100 ml Fecal Coliform or *E. coli*	127 to 499/100 ml Fecal Coliform or *E. coli*	$\geqslant$ 500/100 ml Fecal Coliform or *E. coli*
Lakes, ponds	16[a]	7 [b]	12[c]
Rivers, streams, creek, or canal			2
Springs			1
All	16	7[a]	15

[a] Includes 2 outbreaks where samples were analyzed only for total coliforms (30 TC/100 ml and 30 TC/100 ml).
[b] Includes one outbreak where sample was analyzed for fecal streptococcus (380 FS/100ml) and one outbreak where sample was analyzed for total coliforms (208.5 TC/100ml). [c] Includes one outbreak where sample was analyzed for only for total coliforms (1400 TC/100ml).

the water samples that were collected during the outbreak investigations are assumed to be a measure of compliance with EPA guidelines, then 16 (42%) outbreaks occurred in recreational waters that met the EPA guidelines for fresh water (Table V). This includes water samples where only total coliforms were measured; (i.e., it was assumed that the coliforms were fecal coliforms). In an outbreak of *E. coli* O157:H7 in Wisconsin in 1999 (Lee et al. 2002), total and fecal coliforms were detected in water samples collected before and during the outbreak, but the levels detected did not exceed EPA guidelines for recreation in fresh waters.

Outbreaks associated with treated tecreational water

During 1971–2000, almost all (94%) treated-water outbreaks were associated with swimming and wading pools. Pool locations included community centers, parks and campgrounds, water theme parks, motels and hotels, country clubs, day-care centers, schools, and hospitals. *Cryptosporidium*, *Pseudomonas*, and *Giardia* were the three most frequently identified etiologies of outbreaks in treated recreational water (Figure 5). *Cryptosporidium* caused 32% of treated-water outbreaks and 80% of the cases of illness. *Pseudomonas* caused 31% of the outbreaks but only 10% of the illnesses. *Giardia* caused 9% of the outbreaks and 4% of the illnesses. An agent was not identified in 9% of the outbreaks and 4% of the cases of illness. *Cryptosporidium* was an important cause of outbreaks associated with swimming pools with and without wading pools, water slides, wave pools, and interactive water fountains.



* Other category includes adenovirus (1.8%), enterovirus (1.8%), *Campylobacter* (0.9%), hepatitis A (0.9%), norovirus (0.9%), *Salmonella* (0.9%), and both *Shigella* & *Cryptosporidium* (0.9%).

Figure 5.

Pseudomonas primarily caused outbreaks among users of swimming pools with and without hot tubs or whirlpool baths. *Giardia* was an important cause of outbreaks among children using wading pools.

A cryptosporidiosis outbreak in 1998 involved three community swimming pools in Wisconsin (Barwick et al. 2000). A child, later diagnosed with *Cryptosporidium*, had a fecal accident in each of the three pools on three successive days. Poor water quality and low chlorine levels were noted in two cryptosporidiosis outbreaks at an apartment complex and resort in Florida in 2000 (Lee et al. 2002). Fecal material was visible in the apartment pool. At the resort, there were complaints of ''cloudy'' water, and numerous diaper-aged children swam in the pool. In a third Florida outbreak in 2000, an infected child reportedly swam while ill (Lee et al. 2002). In a cryptosporidiosis outbreak that affected 700 members of a large private swim club in Ohio in 2000, oocysts were found in the water and inadequate operation, low chlorine residuals, high bather loads, and fecal accidents were reported (Lee et al. 2002). Another large outbreak of cryptosporidiosis was reported in Nebraska in 2000; 225 cases were associated with a cluster of four pools – outdoor adult and baby pools and indoor adult and baby pools (CDC 2002). Before the outbreak, several fecal accidents had occurred, and there was a two-day period when the baby pool was not chlorinated. In 1995, an outbreak at a water park in Georgia caused an estimated 5,449 cases of cryptosporidiosis after a probable fecal accident in the children's pool; several stool specimens were positive for both *Cryptosporidium* and *Giardia* (Levy et al. 1998). In 1996, an estimated 3,000 persons acquired cryptosporidiosis after being exposed to untreated water at a swimming pool and water from a jet-ski spray while watching a water show at a water park in California (Levy et al. 1998). As in the Georgia outbreak, some stool specimens were also found to be positive for *Giardia*.

Waterborne outbreaks of dermatitis (rash or folliculitis) caused by *Ps. aeruginosa* serotypes 0–11 have been reported since 1975 (McCausland and Cox 1975; Washburn et al. 1976). The rash has been described as intensely pruritic, progressing from a maculopapular to vesiculopustular eruption within hours to several days after exposure (CDC 1980). Extended and painful rashes associated with *Pseudomonas* outbreaks are unusual but have been reported (Lee et al. 2002). Most of these outbreaks have been associated with whirlpool baths and hot tubs, but swimming pool outbreaks have also been reported. Pseudomonads are well adapted to survival in whirlpools, hot tubs, and indoor pools because of the warm water temperatures. These waters are especially prone to contamination during periods of high use when it is difficult to maintain adequate disinfection levels. *Ps. aeruginosa* was identified as the etiologic agent in 36 outbreaks, 35 of which occurred in treated waters. In 16 outbreaks, ill persons reported using both a swimming pool and whirlpool, hot tub, or sauna. Also of interest are reports of conjunctivitis, otitis externa, and other symptoms reported in *Pseudomonas* outbreaks. In recent outbreaks in Alaska and Maine, persons reported nausea, headache, fever, fatigue and sore throat in addition to dermatitis (Lee et al. 2002). In another outbreak in Maine in 2000, 11 persons who were staying at a hotel during a sports tournament reported a rash accompanied by symptoms including ear infection, cough, headache and joint pain (Lee et al. 2002).

Other agents that caused outbreaks in treated water included *Shigella* (4%), chemicals (4%), and *E. coli* O157:H7 (3%). Three *Shigella* outbreaks occurred among children using wading pools or an interactive fountain and the fourth among water park visitors using a water slide. Three swimming pool-associated *E. coli* outbreaks were reported. One outbreak was associated with swimming in a poorly maintained and chlorinated indoor pool, and another occurred at a wading pool frequented by diaper-aged children. The third *E. coli* outbreak occurred at a water park where seven case-patients developed hemolytic uremic syndrome and one person died.

Outbreaks of chemical dermatitis were associated with incorrect dosing of chemicals to adjust the pH of swimming pool water, the addition of chemicals to remove excess chloramines, and high levels of disinfectants. Excess chlorine caused bronchial irritation in one outbreak and rash and conjunctivitis in another. Three cases of chemical keratitis resulted from exposure to bromine in a Vermont hotel swimming pool in February 2000 (Lee et al. 2002). Bromine levels were found to be greater than 5 mg/l.

Several outbreaks were associated with interactive fountains. In 1997, 369 persons became ill with cryptosporidiosis after playing in a sprinkler fountain at a Minnesota zoo (Barwick et al. 2000). The fountain was a popular place for diaper-age children to soak themselves during the heat of the summer. Water was sprayed through the air, drained through grates, collected, passed through a sand filter, chlorinated, and recirculated; however, it was not designed as an interactive fountain. In Massachusetts, nine persons became ill from *Shigella sonnei* in 1997 after play in a wading pool that included a sprinkler fountain. Recirculated water was disinfected with chlorine but not filtered, and many diaper-aged children were observed sitting in the wading pool (Barwick et al. 2000). An outbreak that occurred in August 1999 among 38 persons who visited a Florida beach park was attributed to both *S. sonnei* and *C. parvum* (Lee et al. 2002). The fountain's recirculation, filtration and disinfection systems were not approved by the health department and were inadequate or not completely operational at the time of its use.

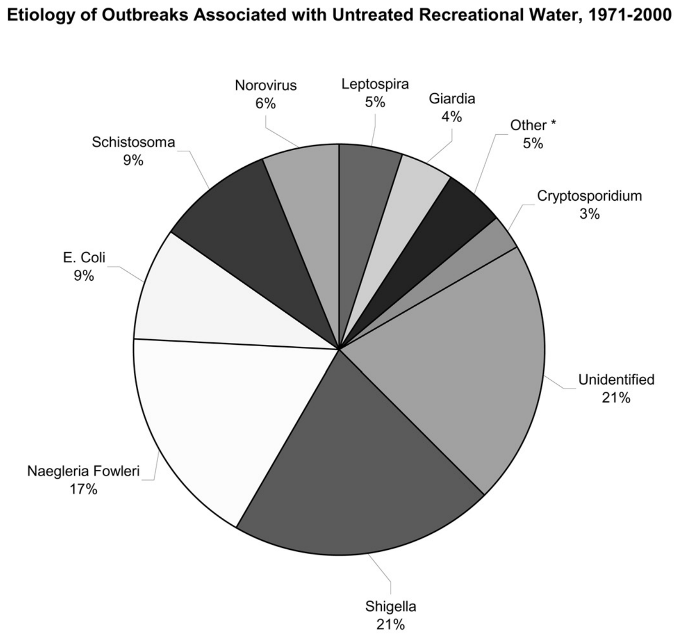
In 1995, an outbreak of *Salmonella* serotype Java was reported in Idaho among persons using a scuba dive pool that had been filled with fish (Levy et al. 1998). In 1999, an outbreak of *Campylobacter jejuni* was associated with a private pool in Florida that had ducks swimming in the pool but did not have continuous chlorine disinfection (Lee et al. 2002).

Two swimming-pool outbreaks of conjunctivitis and pharyngitis in 1980 and 1982 were caused by adenoviruses; the source of contamination was not identified in either outbreak (CDC 1982a, 1983). In 1987, two outbreaks of enterovirus-like illness and aseptic meningitis were reported in an inadequately chlorinated wading pool and a private pool that had been filled with water from a nearby creek (Levine and Craun 1990). In 1989, 20 persons in Louisiana contracted hepatitis after swimming in a campground pool; diaper-aged children were the likely source of contamination (Herwaldt et al. 1991). One norovirus outbreak in January 2000 was associated with swimming in a Wisconsin motel pool during a party where diapered infants were allowed in the water (Lee et al. 2002). Persons became ill within 48 hours after attending the event, and stool specimens tested positive for norovirus. An outbreak of suspected viral etiology occurred among 23 persons who attended three separate pool parties at a California apartment complex in June 1999 (Lee et al. 2002). Swimmers reported that the pool was overcrowded and toddlers were swimming in the pool.

Outbreaks associated with untreated recreational water

An etiologic agent was not identified in 21% of the outbreaks and 30% of the cases of illness associated with bathing activities in untreated water venues during 1971 – 2000 (Figure 6). Most of these outbreaks were associated with lakes and ponds (Table V). *Shigella* was the most frequently identified etiology of outbreaks (21%) and illnesses (29%) in untreated-water outbreaks. Other important agents included *N. fowleri* (17%), *E. coli* O157:H7 (9%), *Schistosoma* causing swimmer's itch (9%), norovirus (6%), *Leptospira* (5%), and *Giardia* (4%). *Cryptosporidium* caused only 3% of the outbreaks, all among swimmers in lakes or ponds. Causes of outbreaks among bathers in springs were due primarily to norovirus or *N. fowleri*.

Sixteen of the 28 single-case outbreaks of PAM were associated with swimming in lakes or ponds. Five PAM cases were associated with swimming in rivers and canals, and three cases



* Other category includes *Salmonella typhi* (1.4%), adenovirus (0.7%), enterovirus (0.7%), hepatitis A (0.7%), *Microcoleus* (0.7%), and *Pseudomonas* (0.7%).

Figure 6.

were associated with bathing in a thermal spring. PAM cases also occurred after facial immersion in a puddle and playing in mud holes and swimming in a waste water holding pond. In one outbreak, the infected person had fallen from a jet ski into the water.

In an *E. coli* O157:H7 outbreak of 36 laboratory-confirmed cases among visitors to a Washington state park in 1999, seven persons were hospitalized; *E.* coli O157:H7 was isolated from samples of lake water and sediment (Lee et al. 2002). *E. coli* O157:H7 also was implicated in a September 1999 outbreak among two young children who had been playing in ditch water in Florida (Lee et al. 2002); both clinical specimens and water samples were positive for *E. coli* O157:H7. A toddler with severe diarrhea reportedly swam in a Connecticut lake during a one-week period before an outbreak of *E. coli* O121:H19 in 2000 (Lee et al. 2002); lake water sampled after the outbreak was positive for total and fecal coliforms.

In a New Jersey park, at least 300 cases of shigellosis occurred in a 1994 outbreak among bathers in the swimming area of a reservoir where numerous fecal accidents had occurred and people were seen rinsing diapers (Kramer et al. 1996). During 1995 – 1996, swimming in a lake in Colorado contaminated with human feces caused 120 persons to become ill in two separate outbreaks; in a Pennsylvania outbreak where most cases occurred among children who were playing in the sand close to the water, soiled diapers were found near the implicated lake (Levy et al. 1998). *S. sonnei* was the cause of two outbreaks at freshwater lakes in Minnesota in 2000; in one outbreak, a large number of children were swimming, and a fecal accident was the likely source of contamination (Lee et al. 2002).

In August 2000, a cryptosporidiosis outbreak of 220 persons occurred at a Minnesota swimming beach where persons washed babies in the lake while changing diapers (Lee et al. 2002). Three persons in Indiana became ill with cryptosporidiosis in 1996 after heavy rains washed cattle feces into a lake (Levy et al. 1998). In Massachusetts, 18 persons were confirmed with *G. intestinalis* in a 1999 outbreak after swimming in a local pond that had high coliform levels (Lee et al. 2002). Two outbreaks of typhoid fever in 1971 and 1972 affected 11 children who swam and played in drainage pools and ditches contaminated with sewage (CDC 1973; Klein 1972).

An outbreak of conjunctivitis and pharyngitis attributed to enterovirus was reported among swimmers at a Wisconsin lake in 1983; the source of the contamination was not identified (CDC 1984). Adenovirus serotype 3 was isolated from clinical and water samples in a 1991 outbreak of 595 persons who reported conjunctivitis, pharyngitis, and fever after swimming in a pond in North Carolina (Moore et al. 1993). In Missouri in 1971, six persons contracted hepatitis A after swimming in a sewage-contaminated river (anon. 1971). In three norovirus outbreaks that occurred among bathers at lakes, fecal contamination from the bathers or sewage was identified as the source of contamination. In the four remaining norovirus outbreaks, a source of contamination was not identified. In one of two norovirus outbreaks in thermal springs, poor personal hygiene was the likely source of contamination.

The largest outbreak of leptospirosis ever reported in the United States occurred in Illinois during 1998 among competitors in a triathlon; 375 persons became ill after swimming in a lake; 28 were hospitalized (Barwick et al. 2000; CDC 1998). In 1991, an outbreak of leptospirosis was associated with swimming in a rural pond in Illinois; *Leptospira interrogans* was found in urine specimens from cases and in pond water (Moore et al. 1993). Swimming in waters contaminated by animal urine was the likely explanation for an outbreak of leptospirosis among 21 persons who participated in an adventure race in Guam in July 2000 (Lee et al. 2002). These persons reported various outdoor exposures including swimming in a river and a reservoir. *Leptospira* was confirmed via serology, and the epidemiologic investigation demonstrated that swimming in the reservoir, submerging one's head in the reservoir and swallowing water while swimming were significant risk factors for illness.

Discussion

The discussion includes a comparison of the recently reported 2001 – 2002 outbreak statistics (Yoder et al. 2004) and the 1971 – 2000 statistics. During 2001 – 2002 Yoder et al. reported outbreaks that included: 30 gastroenteritis outbreaks associated with recreation in lakes, pools, a river, a pool/hot spring, and a puddle; eight dermatitis outbreaks reported among persons who swam in a lake or used both a pool and spa; seven single-case outbreaks of PAM associated with lakes; one single-case outbreak of PAM associated with a river; two outbreaks of acute respiratory illness associated with exposure to an accidential release of chlorine gas at an indoor and outdoor pool; and two outbreaks of acute respiratory illness associated with exposure to an accumulation of chloramines at indoor pools. The seasonal distribution of these outbreaks was similar to that reported for outbreaks during 1971 – 2000.

Outbreaks associated with recreational water continued to increase during 2001 – 2000 when, an average of 25 outbreaks per year were reported. During 1991 – 1995 and 1996 – 2000, respectively, an annual average of 14 and 18 outbreaks were reported. This increase could reflect improved surveillance and reporting at the local and state level, a true increase in the number of outbreaks, or more likely, a combination of these factors. Although increased reporting of outbreaks occurred in both treated and untreated recreational water, a greater increase occurred in treated-water outbreaks where, on average, 14.5 outbreaks per year were reported during 2001 – 2002 compared to 5 and 9 outbreaks per year during 1991 – 1995 and 1996 – 2000, respectively. A relative modest increase occurred for outbreaks in untreated water where outbreaks increased from 8 to 9.5 per year during 1996 – 2000 to 2001 – 2002.

In recent years, cases of illness associated with these outbreaks have exceeded those reported in drinking water outbreaks. During 1995 – 2000, 13,131 illnesses were reported in recreational water outbreaks compared with 9,094 illnesses in drinking water outbreaks. During 2001 – 2002, this difference was even greater, as the number of illnesses reported in recreational water outbreaks was more than two-fold greater than illnesses in drinking water outbreaks.

Dose-response studies have shown that relatively few organisms of *Cryptosporidium, Giardia, Shigella* and *E. coli* O157:H7 are required to cause infection (Rendtorff 1954; DuPont et al. 1995, 1989; Moyer 1999; Benenson 1995). Thus, the unintentional ingestion of a single mouthful of contaminated water while swimming and bathing can cause illness, even in non-outbreak settings (Seyfried et al. 1986; Calderon et al. 1991). Swimming is essentially communal bathing, and pathogens can be introduced by the rinsing of soiled bodies and other bather activities. Most recreational outbreaks reported both during 1971 – 2000 and 2001 – 2002 occurred while swimming in lakes and swimming pools that were contaminated by fecal accidents and children in diapers and where bather overcrowding was suspected. However, in outbreaks during 2001 – 2002, bather overcrowding and diapered children were reported more frequently in treated water venues and less frequently in untreated water venues. High temperatures, special events, and holidays can result in bather overcrowding, and weather conditions (e.g., wind, rain, drought) can affect the water quality in pools and lakes. Outbreaks were also caused by contamination of untreated water by sewage discharges, watershed runoff from agricultural and residential areas, algal blooms, and various animal and avian species. Wild and domestic animals, as well as infected humans, can be sources of pathogens that can cause gastroenteritis, dermatitis, or other illnesses.

During both 1971 – 2000 and 2001 – 2002, relatively few (14 – 15%) outbreaks were of undetermined etiology. Outbreaks of undetermined etiology primarily occurred in untreated waters. Protozoan and bacterial agents caused almost three-fourths of the outbreaks reported during 1971 – 2000 and slightly more than half of the outbreaks reported during 2001 – 2002. During 2001 – 2002, norovirus was identified in 10% of the outbreaks compared to only 4% during 1971 – 2000. This may largely be due to improved laboratory capabilities and increased analyses. Outbreaks associated with chemical exposures were also more important during 2001 – 2002 (8%) than during 1971 – 2000 (2%). Outbreaks in 2001 and 2002 emphasize the importance of adequate operation, maintenance, and training; illnesses associated with exposure to chlorine gas or chloramines were characterized by respiratory symptoms, nausea, skin rash, and eye and throat irritation (Yoder et al. 2004). Chloramine exposures occurred at indoor pools, and chlorine gas exposures occurred at an indoor and an outdoor pool.

Outbreaks attributed to bacteria, such as *Shigella* and *E. coli* O157:H7, were associated primarily with swimming in fresh water (i.e., lakes, ponds, reservoirs). In contrast, most of the outbreaks caused by *Cryptosporidium* and *Giardia* were reported in chlorinated, filtered pool waters. Although *Cryptosporidium* and *Pseudomonas* were the principal causes of outbreaks in treated recreational water both in 2001 – 2002 (56%) and 1971 – 2000 (63%), other etiologies differed. During 2001 – 2002 compared to 1971 – 2000, there were increased percentages of treated-water outbreaks caused by norovirus (10 vs. < 1%) and *Shigella* (7 vs. 4%). No *Giardia* outbreaks were reported in treated water during 2001 – 2002, whereas 9% of the treated-water outbreaks during 1971 – 2000 were caused by *Giardia*. In untreated recreational waters, *N. fowleri, Cryptosporidium*, norovirus, and toxigenic *E. coli* increased in importance.

During 2001 – 2002 compared to 1971 – 2000, there were increased percentages of untreated-water outbreaks caused by *N. fowleri* (38 vs. 17%), *Cryptosporidium* (10 vs. 3%), norovirus (14 vs. 6%), and toxigenic *E. coli* (14 vs. 9%). No *Shigella* outbreaks were associated with treated recreational water during 2001—2002, whereas 21% of the treated-water outbreaks during 1971 – 2000 were caused by *Shigella*.

Cryptosporidium and *Giardia* are relatively resistant to disinfection by chlorine, and some pool filtration systems might not be effective in removing oocysts. Poor maintenance or operation and inadequate water treatment were identified as deficiencies that contributed to 52% of all outbreaks reported in treated water venues during 1971 – 2000. Similar statistics were reported during 2001—2002. Even pools with filters and disinfection practices capable of removing or killing these parasites may require hours or even a day to completely recirculate and disinfect the pool water once it becomes contaminated (e.g., by a fecal accident). Swimmers remain at risk until the contaminated water is recirculated through an effective water treatment process, and the water can become recontaminated if persons continue to swim. The risk for transmission of waterborne pathogens can also increase because of problems in the design of pools that result in areas with poor water circulation, mixing of water from different pools during filtration, and the depletion of residual disinfection levels (Carpenter et al. 1999; CDC 1976).

Although most bacterial outbreaks were associated with untreated water, outbreaks of bacterial etiology also occurred in treated water where residual disinfectant levels would be expected to prevent these outbreaks. Low chlorine levels found during an outbreak at a large water park emphasize the importance of frequent monitoring and maintaining adequate chlorination levels in large shallow pools, especially those used by young children. Since fecal contaminants and other organic material can rapidly consume the available chlorine, low chlorine residuals indicate possible water quality deterioration.

Although gastroenteritis is the most frequently reported illness in recreational water outbreaks, other illness have been reported and efforts to prevent these illnesses should not be forgotten. Outbreaks of *Pseudomonas* dermatitis are preventable if water is maintained at a pH of 7.2 – 7.8 with free, residual chlorine levels in the range of 2.0 – 5.0 mg/L (CDC 1981). A person's susceptibility and immersion time, along with the number of bathers per unit area, also influence the risk for infection (Highsmith and McNamara 1988). Close attention to bather overcrowding, as well as frequent disinfectant level monitoring and attention to maintaining adequate treatment, can help prevent these outbreaks.

Spring water was implicated in seven outbreaks during 1971 – 2000, five of which were associated with thermal springs. Springs and geothermal pools pose an increased risk to swimmers because their high levels of minerals and elevated temperatures may contribute to microbial growth and contamination. Improved education of patrons and staff about good hygiene practices is important, and in some instances, supplementary treatment or other measures may be needed to reduce risks.

Leptospira spp. can be found frequently in wild animal urine, and leptospirosis can be acquired through abrasions, inhalation of aerosols, or ingestion of water while swimming (Nelson et al. 1973; Lee et al. 2002). Swimmers should be educated about the potential risks of swimming in ponds and lakes that are not secured from entry by wild animals and that may be subject to contamination by wild or domestic animals.

The extent of the problem of cercarial dermatitis due to freshwater exposure is unknown, but it is likely that it occurs more frequently than what has been reported. Cercariae occur naturally in ecosystems that bring snails and birds closely together, and a number of the freshwater lakes in the United States have the potential to cause dermatitis among swimmers (Verbrugge et al. 2004). Persons should pay careful attention to where they swim, avoid shallow swimming areas known to be appropriate snail habitats in lakes associated with cercarial dermatitis, and report any incidents to their local health department to prevent further illnesses.

Inadequate pool operation and maintenance were often reported as contributing factors to treated-water outbreaks. Analysis of over 22,000 pool inspection records revealed that the majority of pool inspections had at least one pool code violation for water quality, recirculation system, or pool management and 8.3% of inspections resulted in immediate pool closure (CDC 2003). In partnership with a consortium of local and national pool associations, the CDC developed health communication materials for staff who work at treated water venues. This includes a caution to the public about health risks associated with swimming and wading pools, ways to reduce these risks, and a recreational water outbreak investigation tool kit for public health professionals (www.cdc.gov/healthyswimming). CDC has also developed and published technical information concerning laboratory diagnostics and a recreational water outbreak investigation toolkit that can be used by public health professionals.

Training of water park and pool managers, operators, and staff should include information about the transmission of waterborne illnesses and the critical role of treatment (i.e., disinfection, pH control, and filtration), operation/maintenance, and monitoring in preventing these illnesses. Health education activities should stress the potential for contamination by overcrowding, fecal accidents, and diaper-aged children. Good hygiene practices are required. Adequate toilet and diaper-changing facilities should be provided, and showers required before bathing. Although difficult to enforce, an important measure is preventing persons, especially young children from entering recreational waters if they are experiencing or convalescing from a diarrheal illness. The development of effective policies regarding fecal accidents and limiting the number of bathers in recreational water facilities are also needed, but additional research is needed, especially for water quality indicators and monitoring to assess bather contamination (CDC 2001). Contamination of pools and freshwater venues may require lengthy periods of closure or other ways to limit use before swimming can resume.

Because of the severe consequences associated with PAM, it is important to educate the public about the risks of PAM when swimming in certain locations. Since the amoebas associated with PAM are believed to enter through the nasal passage, limiting the amount of water forced into the nasal passages during jumping or diving by holding the nose or wearing nose plugs can reduce the risk of infection.

The effectiveness of health communication messages should be also assessed. For example, although cercarial dermatitis was a known problem at several of the lakes implicated in outbreaks during 1999–2000, signs posted by the health department regarding this problem were ignored by swimmers. Also, one gastroenteritis outbreak involved persons who swam in a lake that was clearly marked with signs indicating that the lake was unsafe for swimming. Additional microbial indicators and monitoring for fecal contamination may also be needed for freshwater recreational areas potentially contaminated by sewage. When one or more samples were collected during the outbreak investigations, it was surprising to find that current fecal indicators were present in relatively low numbers, and although the data are limited to only 13 outbreaks, investigators reported that the water quality had not exceeded state or local bathing water limits. In addition, limited water quality data are available for 26% of the outbreaks in fresh water. If it is assumed that water samples collected during the outbreak investigation reflect compliance samples, almost half of these outbreaks would have occurred in freshwaters that did not exceed EPA guidelines. It should be recognized that investigations were conducted after illnesses were reported, and the water quality of samples collected then might reflect improved water quality. However, these findings suggest the need for additional research on appropriate health indicators and monitoring frequency.

Current efforts by EPA under the Beaches Environmental Assessment, Closure, and Health (BEACH) program are aimed at reducing the risk for infection attributed to fresh and marine recreational water by strengthening water quality standards and monitoring frequency. Other activities include evaluating faster laboratory test methods, assessing sources of contamination, and increasing health- and methods-related research. To improve public access to information regarding both the quality of the water at their beaches and health risks associated with swimming in polluted water, EPA's Beach Watch (www.epa.gov/waterscience/beaches) provides online information regarding water quality, local protection programs, and other beach-related programs. Ongoing epidemiologic studies by EPA will provide information about the effectiveness of new, rapid (results in less than 2 hours) water quality indicator methods (www.epa.gov/nerlcwww/neearnerl.htm) and will be used to develop new EPA recreational water quality guidelines.

Conclusions

Although reporting is incomplete and the accuracy of case counts vary, surveillance activities have helped identify the types of recreational water, deficiencies and sources of contamination, and etiologic agents that are important causes of outbreaks in the United States. This information and recent increases in the number of reported outbreaks suggest the need to develop improved prevention and control to provide safe recreational waters. The prevention of illness from contaminated recreational waters requires a comprehensive approach that includes the control and remediation of environmental contamination, improved training of beach/pool managers and maintenance staff, and enhanced health education activities. To be effective, prevention and control programs depend on the close collaboration of local, state, and federal public health and regulatory agencies. It is also important that ways be developed to share surveillance, monitoring, and research information.

An important limitation of the outbreak surveillance data is the lack of information about sporadic waterborne illness. The outbreak statistics do not reflect the true incidence of waterborne outbreaks or illness, and additional regulations and control strategies may be necessary to prevent endemic waterborne illness. Recently initiated epidemiologic studies of endemic disease risks should help provide information in this regard.

Increased outbreak surveillance activities should also be considered to improve outbreak recognition and investigation, especially in localities where exposures may differ from the reported outbreaks in terms of recreational activities, water temperatures, contamination sources, or other local conditions. The evaluation and reporting of recreational-associated waterborne outbreak statistics from other countries is also encouraged.

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References

Anonymous. 1971. Infectious hepatitis outbreak, St. Louis, Missouri. Unpublished report. p 7.

Barwick RS, Levy D, Craun GF, Beach MJ, Calderon RL. 2000. Surveillance for waterborne-disease outbreaks – United States, 1997 – 1998, Morb Mort Weekly Report 49 (No. SS-4), 1 – 35.

Benenson AS, Ed. 1995. Control of Communicable Diseases Manual, American Public Health Association, Washington, DC. p 142.

Cabelli VJ. 1983. Health Effects Criteria for Marine Recreational Waters, Research Triangle Park, NC: US Environmental Protection Agency (EPA publication 600/1-80-031).

Calderon RL, Mood EW, Dufour AP. 1991. Health effects of swimmers and nonpoint sources of contaminated water, Inter J Env Health Research 1:21.

Carpenter C, Fayer R, Trout J, Beach MJ. 1999. Chlorine disinfection of recreational water for *Cryptosporidium parvum*. Emerg Infect Dis 5:579 – 84.

CDC. 1973. Typhoid fever-Alabama. Morb Mort Weekly Report 22(19):167.

CDC. 1973. Foodborne Outbreaks, Annual Summary 1972. Atlanta, GA: U.S. Dept. of Health and Human Services (Publication 76-8185, November).

CDC. 1974. Foodborne and Waterborne Disease Outbreaks, Annual Summary 1973. Atlanta, GA: U.S. Dept. of Health and Human Services (Publication 75-8185, August).

CDC. 1976. Swimming Pools: Safety and Disease Control Through Proper Design and Operation. Atlanta, GA: U.S. Dept. of Health and Human Services (Publication 88-8319).

CDC. 1976a. Foodborne and Waterborne Disease Outbreaks, Annual Summary 1974. Atlanta, GA: U.S. Dept. of Health and Human Services (Publication 76-8185, January).

CDC. 1976b. Foodborne and Waterborne Disease Outbreaks, Annual Summary 1975. Atlanta, GA: U.S. Dept. of Health and Human Services (Publication 76-8185, August).

CDC. 1977. Foodborne and Waterborne Disease Outbreaks, Annual Summary 1976. Atlanta, GA: U.S. Dept. of Health and Human Services (Publication 78-8185, October).

CDC. 1979. Foodborne and Waterborne Disease Outbreaks, Annual Summary 1977. Atlanta, GA: U.S. Dept. of Health and Human Services (Publication 79-81385, August).

CDC. 1980. Water-related Disease Outbreaks, Annual Summary 1978. Atlanta, GA: U.S. Dept. of Health and Human Services (HHS Publication 80-8385, May).

CDC. 1981. Water-related Disease Outbreaks, Annual Summary 1979. Atlanta, GA: U.S. Dept. of Health and Human Services (HHS Publication 81-8385, September).

CDC. 1982a. Water-related Disease Outbreaks, Annual Summary 1980. Atlanta, GA: U.S. Dept. of Health and Human Services (HHS Publication 82-8385, February).

CDC. 1982b. Water-related Disease Outbreaks, Annual Summary 1981. Atlanta, GA: U.S. Dept. of Health and Human Services (HHS Publication 82-8385, September).

CDC. 1983. Water-related Disease Outbreaks, Annual Summary 1982. Atlanta, GA: U.S. Dept. of Health and Human Services (HHS Publication 83-8385, August).

CDC. 1984. Water-related Disease Outbreaks, Annual Summary 1983. Atlanta, GA: U.S. Dept. of Health and Human Services (HHS Publication 84-8385, September).

CDC. 1985. Water-related Disease Outbreaks, Annual Summary 1984. Atlanta, GA: U.S. Dept. of Health and Human Services (HHS Publication 99-2510, November).

CDC. 1991. Primary amebic meningoencephalitis – North Carolina. Morb. Mort. Weekly Report 41:437 – 440.

CDC. 1981. Suggested Health and Safety Guidelines for Public Spas and Hot Tubs. Atlanta, GA: U.S. Dept. of Health and Human Services (Publication 99-960).

CDC. 1998. Outbreak of acute febrile illness among athletes participating in triathlons – Wisconsin and Illinois. Morb Mort Weekly Report 47:585 – 8.

CDC. 2001. Notice to readers: responding to fecal accidents in disinfected swimming venues. Morb Mort Weekly Report 50:416 – 417.

CDC. 2003. Surveillance Data from Swimming Pool Inspections — Selected States and Counties, United States, May – September 2002. Morb Mort Weekly Report 52:513 – 6.

Craun GF, Ed. 1990. Methods for the Investigation and Prevention of Waterborne Disease Outbreaks. Cincinnati, OH: US Environmental Protection Agency EPA publication no. 600/1-90/005a).

Craun GF, Frost FJ, Calderon RL, Hilborn ED, Fox KM, Reasoner DJ, Poole CL, Rexing DJ, Hubbs SA, Dufour AP. 2001. Improving waterborne disease outbreak investigations. Int J Env Health Research 11:229 – 243.

Dufour AP. 1984. Health Effects Criteria for Fresh Recreational Waters. Research Triangle Park, NC: US Environmental Protection Agency (EPA publication no. 600/1-84-004).

DuPont H, Levine M, Hornick R, Formal S. 1989. Inoculum size in shigellosis and implications for expected mode of transmission. J Infec Dis 159:1126 – 8.

DuPont HL, Chappel CL, Sterling CR, et al. 1995. The infectivity of *Cryptosporidium parvum* in healthy volunteers. New England J Med 332:855.

Herwaldt BL, Craun GF, Stokes SL, Juranek DD. 1991. Waterborne-disease outbreaks, 1989 – 1990. Morb Mort Weekly Report 40 (No. SS-3), 1 – 21.

Highsmith AK, McNamara AM. 1988. Microbiology of recreational and therapeutic whirlpools. Tox Assess 3:599 – 611.

Klein CA. 1972. Typhoid fever in a trailer camp. EIS Conference April 10 – 14, 1972, Atlanta, GA: U.S. Dept. of Health and Human Services, p 26.

Kramer MH, Herwaldt BL, Craun GF, Calderon RL, Juranek DD. 1996. Surveillance for waterborne-disease outbreaks – United States, 1993 – 1994. Morb Mort Weekly Report 45 (No. SS-1), 1 – 33.

Lee SH, Levy DA, Craun GF, Beach MJ, Calderon RL. 2002. Surveillance for waterborne-disease outbreaks – United States, 1999 – 2000. Morb Mort Weekly Report 51(SS-8), 1 – 48.

Levy DA, Bens MS, Craun GF, Calderon RL, Herwaldt BL. 1998. Surveillance for waterborne-disease outbreaks – United States, 1995 – 1996, Morb Mort Weekly Report 47 (No. SS-5), 1 – 33.

Levine WC, Craun GF. 1990. Waterborne disease outbreaks, 1986 – 1988, Morb Mort Weekly Report 39 (No. SS-1), 1 – 13.

McCausland WJ, Cox PJ. 1975. Pseudomonas infection traced to motel whirlpool. J Environ Health 37:455 – 459.

Moore AC, Herwaldt BL, Craun GF, Calderon RL, Highsmith AK, Juranek DD. 1993. Surveillance for waterborne disease outbreaks – United States, 1991 – 1992, Morb Mort Weekly Report 42 (No.SS-5), 1 – 22.

Moyer NP. 1999. *Shigella*. In: Waterborne Pathogens, American Water Works Association, AWWA M48, Denver CO. pp 115 – 117.

Nelson KE, Ager EA, Galton MM, Gillespie RW, Sulzer, CR. 1973. An outbreak of leptospirosis in Washington State. Amer J Epidemiol 98:336 – 47.

Rendtorff RC. 1954. The experimental transmission of human intestinal protozoan parasites. II. *Giardia lamblia* cysts given in capsules. Amer J Hygiene 59:209 – 220.

Seyfried PL, Tobin RS, Brown NE, Ness PF. 1985. A prospective study of swimming-related illness. I. Swimming-associated health risk, Amer J Public Health 75:1068.

St Louis ME. 1988. Water-related disease outbreaks, 1985 – 1996, Morb Mort Weekly Report 37 (No. SS-2), 15 – 24.

US Environmental Protection Agency, Office of Water. 1986. Ambient water quality criteria for bacteria – 1986. Cincinnati, OH: National Service Center for Environmental Publications (EPA publication no. 440584002).

Verbrugge LM, Rainey JJ, Reimink RL, Blankespoor HD. 2004. Swimmer's itch: Incidence and risk factors. Amer J Public. Health 94(5):738 – 41.

Visvesvara GS, Stehr-Gree JK. 1990. Epidemiology of free-living ameba infections. J Protozool 37(suppl):25S – 33S.

Washburn J, Jacobson JA, Marston E, Thorsen B. 1976. *Pseudomonas aeruginosa* rash associated with a whirlpool. JAMA 235:2205 – 7.